ON THE RATE OF EVAPORATION OF ETHER FROM OILS AND ITS APPLICATION IN OIL-ETHER COLONIC ANESTHESIA.

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(*Read April 23, 1915.*)

It is conceded that the anesthetic agent must get into the blood for distribution and for eventual elimination, whatever theory of general or central anesthesia one may support. The anesthetic agent has normally been introduced into the blood by inhalation or intravenously. It is normally eliminated mainly via the lungs.

The intestinal mucous membrane of vertebrates is well known as an efficient transmitter of gases to and from the blood. Pirogoff[1] appears to have been the first to mention the administration of ether by this route. Liquid ether was used until Magendie gave warning as to the danger of its use and ether vapor was substituted. During the same year Roux,[2] y'Yhedo[3] and Duprey[4] employed liquid ether or aqueous mixtures to induce complete anesthesia. Although Pirogoff's enthusiasm prompted him to predict the supplanting of the inhalation procedure by the rectal method, references to it disappeared from the literature until 1884. Then Mollière[5] revived interest in the method by using a hand bellows for forcing the ether vapor into the intestine. Variations in the technique were introduced during the same year, but the experiences of Yversen, Harter, Bull,[6] Weir,[7] Wancher[8] and Post[9] showed more or less diarrhœa

[1] "Recherches pratique et physiologiques sur l'etherization," St. Petersburg, 1847.

[2] *J. d. l'academie d. Sciences,* 1847, 18.

[3] *Gazette med. d. Paris,* 1847.

[4] *Academie royale de medicine,* March 16, 1847.

[5] *Lyon Medical,* 45, 1884.

[6] *N. Y. Med. J.,* March 3, 1884.

[7] *Med. Rec.,* 1884.

[8] Cong. internat. d. Sciences med., 1884.

[9] *Boston Med. and Surg. J.,* 1884.

and melena as after-effects. These after-effects, which one case of death directly attributable to the procedure, caused the method to again fail in securing serious recognition until 1903 when Cunningham[10] employed air as a vehicle for sweeping the ether vapor into the colon. In 1909 Leuguen, Money and Verliac[11] used oxygen as the vehicle for the ether vapor. Buxton[12] in his splendid book on "Anesthesia" says that he found the procedure most satisfactory for certain operations, for example, those having to do with the mouth, nose, etc., but he remarks "Deaths have occurred." Sutton's[13] introduction of a return flow tube for these gases introduced and unabsorbed constituted a distinct advance in anesthesia by colonic absorption.

In an effort to avoid certain well-known difficulties in intravenous anesthesia, Gwathmey experimented with mixtures of normal saline solution and ether per rectum. The concentration of ether in the aqueous solution was so small that excessive volumes of liquid were needed, and furthermore the ether parted from the solution so very rapidly that experimentation along those lines was abandoned. Gwathmey then applied a solution of ether in olive oil. As oil and ether make perfect solutions in all mixtures, it was his hope to reduce the total bulk of the fluid introduced into the colon by using a stronger solution of ether in oil than is possible with any known aqueous mixture. As oils are lubricants, it was also hoped to avoid the irritation of the mucous membrane previously noted. The ether may always be separated from the oil by warming, but unless the temperature of the mixture is suddenly raised to an excessively high point, the ether passes off deliberately. It was thought that the evaporation of the ether would induce some cooling of the mixture with a consequent checking of the evaporation and its absorption. These premises coupled with slow absorption by the colon in comparison with the rapid elimination by the lungs would auto-

[10] Cunningham and Leahy, *Boston Med. and Surg. J.*, April 30, 1905; *Vide* also Dumont, *Correspond. Bl. f. Schweitzer Aerzte*, 1903; 1904; 1908; Krugeline, *Wiener klin. Woch.*, Dec., 1904.

[11] *Compt. rend. Soc. Biol.*, June, 1909.

[12] "Anesthesia," London, 1907.

[13] For full account of technique and literature, see "Anesthesia," by Gwathmey and Baskerville, Appleton, New York, pp. 431–457, 1914.

matically regulate any anesthesia that might be induced in this manner. As a result, Gwathmey presented a paper before the seventeenth International Medical Congress in London in 1913 on the work with animals done by himself and Wallace.

At the request of my co-laborer, Gwathmey, I undertook an investigation on the rate of evaporation of ether from oils to secure the following information that might be of service to him in his further application of his ideas with human subjects:

1. A comparison of the rate of evaporation of ether from different mixtures of ether and the same oil.

2. A comparison of the rate of evaporation of ether from the same per cent. mixtures of different oils and ether.

3. The influence of surface on the rate of evaporation was determined.

As the result of much preliminary experimentation, the following mode of procedure was settled upon. Large glass tubes were calibrated to 1 c.c. from 20 c.c. to 105 c.c. The mixtures of 25, 50 and 75 per cent. of oil and ether were carefully placed in the tubes. The tubes were weighted with lead and placed in a thermostat, whose temperature was so regulated as not to vary more than $\pm 0.03°$ C. from 37° C., the same being controlled by a toluene + mercury temperature regulator. All connections (gas, water, etc.) were made with lead pipe for safe use over night, as occasion arose. The water in the bath was stirred by a system of paddles and shaft operated through belt and pulleys by a small hot air engine. The tubes were immersed in the bath to within 2 cm. of the tops. During the first five minutes two readings were made in each case to get the highest point to which the volumes expanded upon heating up to 37° C. After that readings were made every five minutes for two or three hours.

Since the evaporation of any liquid depends upon the partial pressure of that liquid at its surface, the higher the glass wall above the surface of the oil-ether mixture, the heavier the column of ether vapor resting on the surface of the mixture, the slower will be the evaporation, consequently the different oil mixtures with the different percentages of ether were experimented with in the same tube filled to the same height in each experiment.

In the experiments to determine the influence extent of surface played upon the rate of evaporation, the same precautions were taken as to height of walls of the containing vessels. In the largest areas worked with, this involved using as much as 600 c.c. of the mixture. As the 75 per cent. mixture had been found most satisfactory clinically, this was determined with that mixture only.

The ether used was that prepared under my supervision and was 97 per cent. absolute with 3 per cent. absolute alcohol, being free from acids, aldehydes, and water.

The oils used were of three types, vegetable, animal and mineral, being respectively, olive, cotton seed, corn, peanut and soya-bean; cod-liver and lanolin (anhydrous); and Russian mineral oil. All the vegetable oils, except olive, were refined by a process devised by

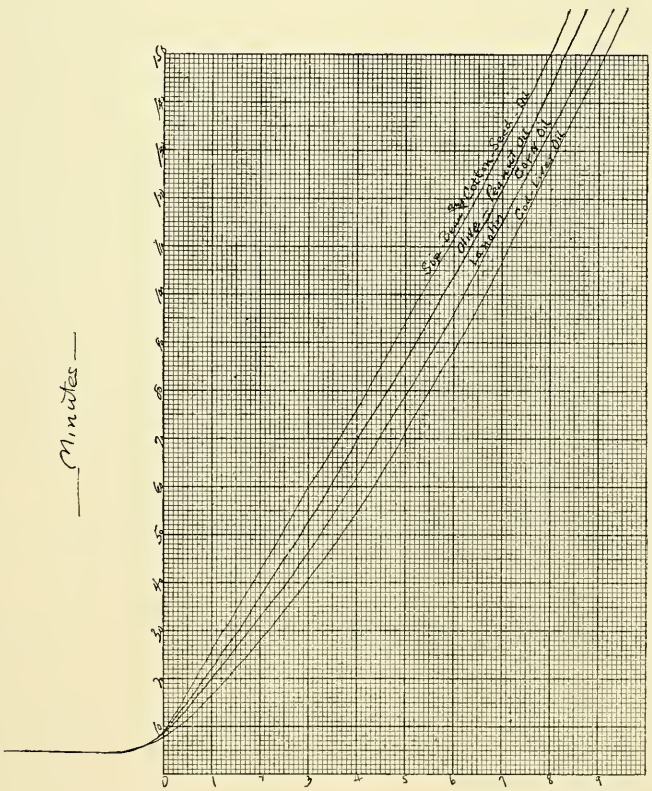

CHART I.

the author[14] and were neutral. The other oils were purchased in the open market.

The experimental work was carried out by Mr. Hyman Storch, under my direction.

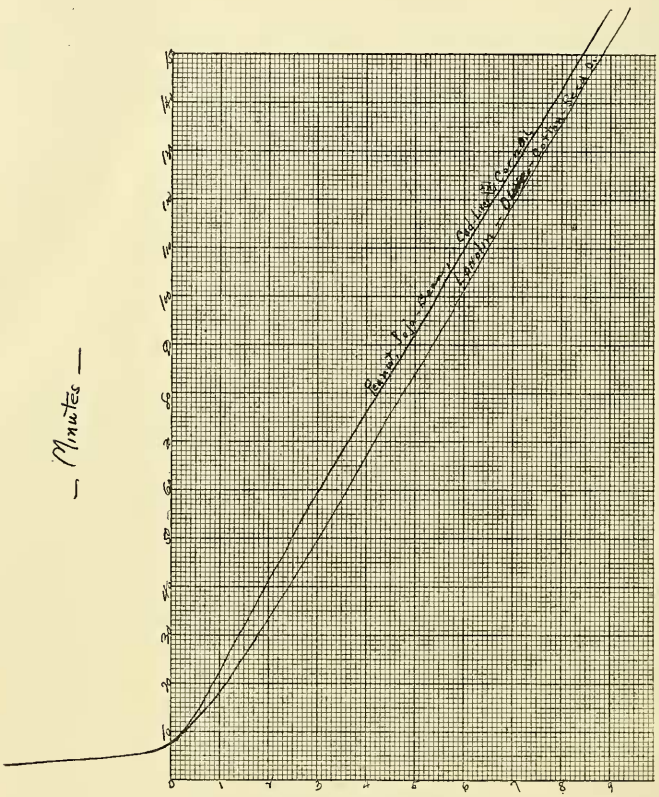

Chart II.

The data obtained for the 25, 50 and 75 per cent. mixtures vegetable and animal oils are shown graphically in Charts I., II. and III. In the curves the abscissæ show the percentage of ether evaporated (based on volume measurements) and the ordinates time of the evaporation.

Chart IV. (selected at random from charts made for each oil) shows the difference in rate of evaporation 25, 50 and 75 per cent. mixtures with one oil.

[14] "Refining Oils," *Oil, Paint and Drug Reporter*, May, 1915.

Chart V. shows the effect of increased surface on the rate of evaporation. One oil only was selected to show the principle, which is: the rate of evaporation bears a direct ratio to the surface exposed.

These experiments were made in glass, hence they do not disclose all the factors in the conduct of such mixtures in contact with the walls of the colon, for there the principles of osmosis and diffusion are involved. But these observations demonstrated several striking facts:

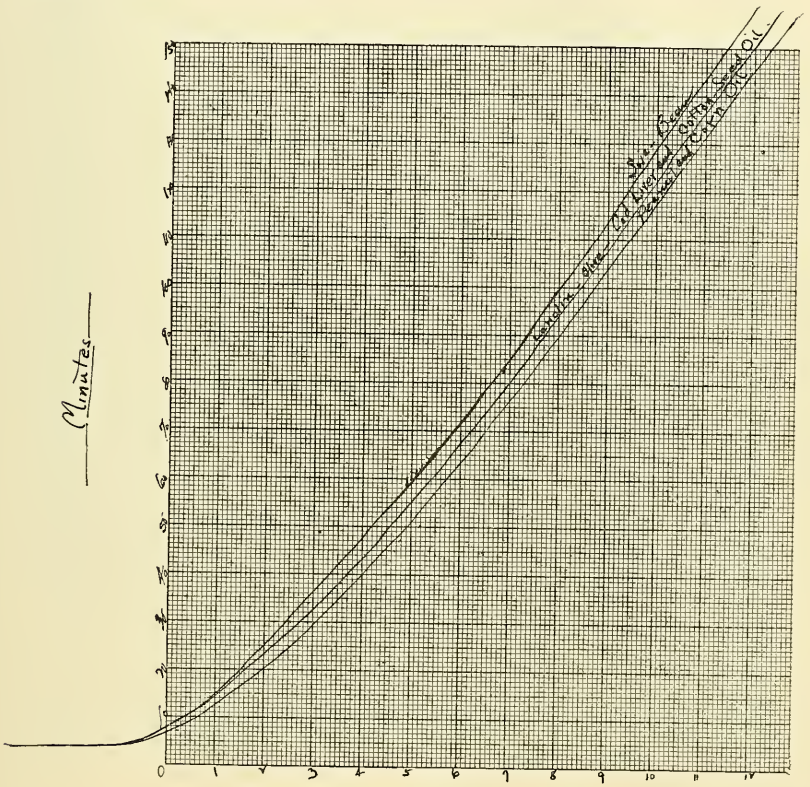

CHART III.

1. While ether boils at 34.6° C., it does not escape violently from an oil-ether mixture, as from an aqueous mixture when the mixture is heated higher, namely, to the body temperature of 37° C.

2. The *rate* of separation of ether from the oil quickly acquires a definite and fairly fixed speed.

The significance of this conduct cannot fail to be of great importance, for by this means the proper content of ether may be main-

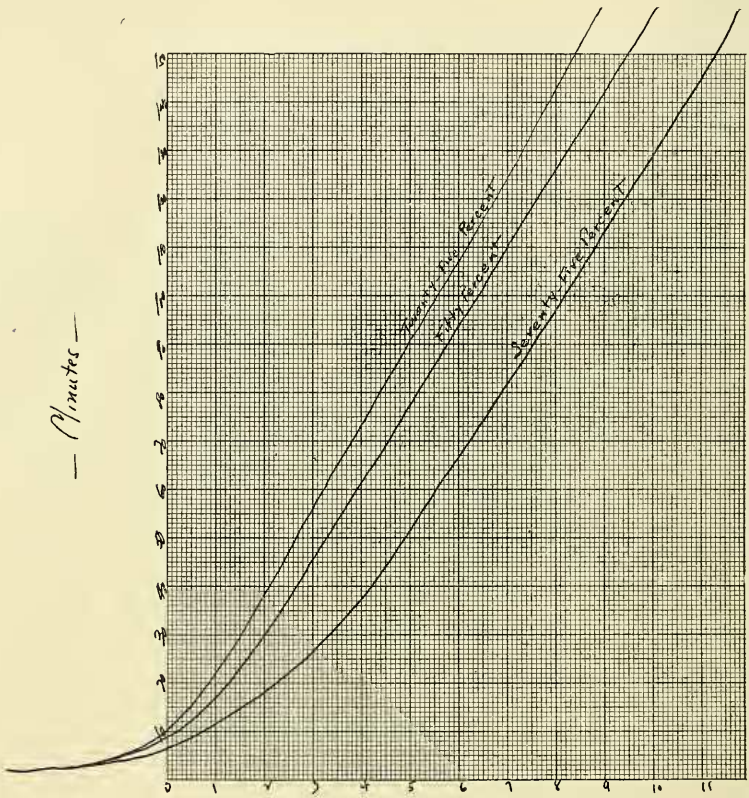

Chart IV.

tained in the blood to produce any desired physiological effect that has a quantitative relation thereto, for example, the third or surgical stage of anesthesia.[15]

The last mentioned has been demonstrated clinically by Wallace, who found respiration and blood pressure fully maintained, and Gwathmey and others with records to date of about 1,000 human cases. So far, not a case of post-ether pneumonia has been encoun-

[15] In this connection it may be stated that about 30 mils of a 75 per cent. mixture to 20 lbs. of body weight is administered as an enema.

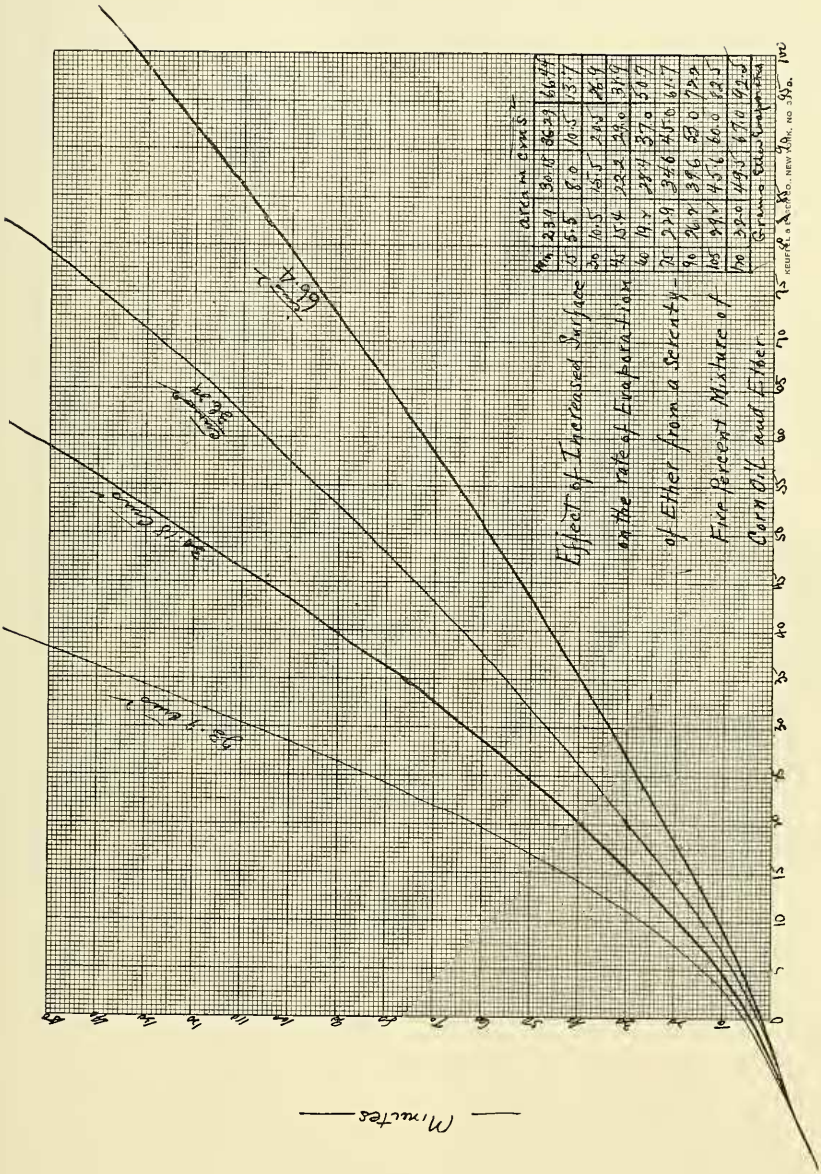
Effect of Increased Surface
on the rate of Evaporation
of Ether from a Secret -
Five Percent Mixture of
Corn Oil and Ether.
Minutes

CHART V.

tered. The after-effects usually associated with inhalation anesthesia, unless induced by the most improved modern technique, are virtually absent, including post-anesthetic nausea. Its use for special cases involving the head, breathing passages, etc., is superior. Although having had the privilege of attending clinics, I am not qualified to pass judgment upon its value, but from what I have learned, if necessary, "Give it to me that way."

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